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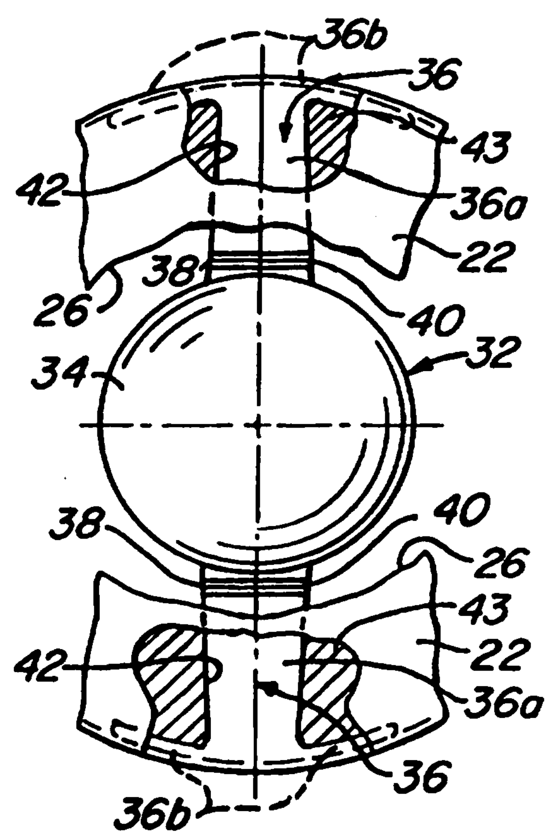
(54) Title: ACCOMMODATING INTRAOCULAR LENS HAVING T-SHAPED HAPTICS

(57) Abstract

An accommodating intraocular lens (32) having T-shaped haptic (36) extending from diametrically opposite edges of an optic (34) for implantation within a capsular bag (20) within an eye (10) having a posterior capsule (24) and an anterior capsule remnant (22) forming an anterior capsule opening (26) surrounded by an anterior capsular rim (22). The lens (32) is placed in the bag (20) with the outer haptic T ends (36b) between the capsular rim (22) and the posterior capsule (24) to accurately center the lens (32) in the bag (20). Fibrosis occurs about the T ends (36b) to fixate them in the bag (20) and about haptic plate portions narrower than the optic diameter between the optic (34) and the T ends (36b) and to form haptic pockets (25) containing the haptic plate portions so that natural contraction and relaxation of the ciliary muscle effects vision accommodation movement of the optic (34). One embodiment has thickened, contoured haptic (202) which slide, upon ciliary muscle contraction, relative to the posterior capsule (24) to provide enhanced anterior movement of the optic (34) for accommodation.



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Description

Accommodating Intraocular Lens Having T-Shaped Haptics

Technical Field

This invention relates generally to an intraocular lens for a human eye and more particularly to a novel accommodating intraocular lens to be implanted within a natural capsular bag in the eye having a posterior side formed by the posterior capsule of the natural ocular lens and an anterior opening circumferentially surrounded by a remnant of the anterior capsule of the natural ocular lens.

Background Art

The human eye has an anterior chamber between the cornea and the iris, a posterior chamber behind the iris containing a crystalline lens, a vitreous chamber behind the lens containing vitreous humor, and a retina at the rear of the vitreous chamber. The crystalline lens of a normal human eye has a lens capsule attached about its periphery to the ciliary muscle of the eye by zonules and containing a crystalline lens matrix. This lens capsule has elastic optically clear anterior and posterior membrane-like walls commonly referred to by opthalmologists as anterior and posterior capsules,

respectively. Between the iris and ciliary muscle is an annular crevice-like space called the ciliary sulcus.

The human eye possesses natural accommodation capability. Natural accommodation involves relaxation and constriction of the ciliary muscle by the brain to provide the eye with near and distant vision. This ciliary muscle action is automatic and shapes the natural crystalline lens to the appropriate optical configuration for focusing on the retina the light rays entering the eye from the scene being viewed.

The human eye is subject to a variety of disorders which degrade or totally destroy the ability of the eye to function properly. One of the more common of these disorders involves progressive clouding of the natural crystalline lens matrix resulting in the formation of what is referred to as a cataract. It is now common practice to cure a cataract by surgically removing the cataractous human crystalline lens and implanting an artificial intraocular lens in the eye to replace the natural lens. The prior art is replete with a vast assortment of intraocular lenses for this purpose.

Intraocular lenses differ widely in their physical appearance and arrangement. This invention is concerned with intraocular lenses of the kind having a central optical region or optic and haptics which

extend outward from the optic and engage the interior of the eye in such a way as to support the optic on the axis of the eye.

Up until the late 1980s, cataracts were surgically removed by either intracapsular extraction involving removal of the entire human lens including both its outer lens capsule and its inner crystalline lens matrix, or by extracapsular extraction involving removal of the anterior capsule of the lens and the inner crystalline lens matrix but leaving intact the posterior capsule of the lens. Such intracapsular and extracapsular procedures are prone to certain post-operative complications which introduce undesirable risks into their utilization. Among the most serious of these complications are opacification of the posterior capsule following extracapsular lens extraction, intraocular lens decentration, cystoid macular edema, retinal detachment, and astigmatism.

An improved surgical procedure called anterior capsulotomy was developed to alleviate the above and other post-operative complications and risks involved in intracapsular and extracapsular cataract extraction. Simply stated, anterior capsulotomy involves forming an opening in the anterior capsule of the natural lens, leaving intact within the eye a capsular bag having an elastic posterior capsule, an anterior capsular remnant

or rim about the anterior capsule opening, and an annular crevice, referred to herein as a cul-de-sac, between the anterior capsule remnant and the outer circumference of the posterior capsule. This capsular bag remains attached about its periphery to the surrounding ciliary muscle of the eye by the zonules of the eye. The cataractous natural lens matrix is extracted from the capsular bag through the anterior capsule opening by phacoemulsification and aspiration or in some other way after which an intraocular lens is implanted within the bag through the opening.

A relatively recent and improved form of anterior capsulotomy known as capsulorhexis is essentially a continuous tear circular or round capsulotomy. A capsulorhexis is performed by tearing the anterior capsule of the natural lens capsule along a generally circular tear line substantially coaxial with the lens axis and removing the generally circular portion of the anterior capsule surrounded by the tear line. A continuous tear circular capsulotomy or capsulorhexis, if performed properly, provides a generally circular opening through the anterior capsule of the natural lens capsule substantially coaxial with the axis of the eye and surrounded circumferentially by a continuous annular remnant or rim of the anterior capsule having a relatively smooth and continuous inner edge bounding

the opening. When performing a continuous tear circular capsulorhexis, however, the anterior rim may sometimes be accidentally torn, nicked, or otherwise ruptured, which renders the rim prone to tearing when the rim is stressed, as it is during fibrosis as discussed below.

Another anterior capsulotomy procedure, referred to as an envelope capsulotomy, involves cutting a horizontal incision in the anterior capsule of the natural lens capsule, then cutting two vertical incisions in the anterior capsule intersecting and rising from the horizontal incision, and finally tearing the anterior capsule along a tear line having an upper upwardly arching portion which starts at the upper extremity of the vertical incision and continues in a downward vertical portion parallel to the vertical incision which extends downwardly and then across the second vertical incision. This procedure produces a generally archway-shaped anterior capsule opening centered on the axis of the eye. The opening is bounded at its bottom by the horizontal incision, at one vertical side by the vertical incision, at its opposite vertical side by the second vertical incision of the anterior capsule, and at its upper side by the upper arching portion of the capsule tear. The vertical incision and the adjacent end of the

horizontal incision form a flexible flap at one side of the opening. The vertical tear edge and the adjacent end of the horizontal incision form a second flap at the opposite side of the opening.

A third capsulotomy procedure, referred to as a beer can or can opener capsulotomy, involves piercing the anterior capsule of the natural lens at a multiplicity of positions along a circular line substantially coaxial with the axis of the eye and then removing the generally circular portion of the capsule circumferentially surrounded by the line. This procedure produces a generally circular anterior capsule opening substantially coaxial with the axis of the eye and bounded circumferentially by an annular remnant or rim of the anterior capsule. The inner edge of this rim has a multiplicity of scallops formed by the edges of the pierced holes in the anterior capsule which render the annular remnant or rim prone to tearing radially when the rim is stressed, as it is during fibrosis as discussed below.

Intraocular lenses also differ with respect to their accommodation capability, and their placement in the eye. Accommodation is the ability of an intraocular lens to accommodate, that is, to focus the eye for near and distant vision. Certain patents describe alleged accommodating intraocular lenses.

Other patents describe non-accommodating intraocular lenses. Most non-accommodating lenses have single focus optics which focus the eye at a certain fixed distance only and require the wearing of eye glasses to change the focus. Other non-accommodating lenses have bifocal optics which image both near and distant objects on the retina of the eye. The brain selects the appropriate image and suppresses the other image, so that a bifocal intraocular lens provides both near vision and distant vision sight without eyeglasses. Bifocal intraocular lenses, however, suffer from the disadvantage that each bifocal image represents only about 40% of the available light and the remaining 20% of the light is lost in scatter.

There are four possible placements of an intraocular lens within the eye. These are (a) in the anterior chamber, (b) in the posterior chamber, (c) in the capsular bag, and (d) in the vitreous chamber. The intraocular lenses disclosed herein are for placement within the capsular bag.

Disclosure of Invention

This invention provides an improved accommodating intraocular lens to be implanted within a capsular bag of a human eye which remains intact within the eye after removal of the crystalline lens matrix from the

natural lens of the eye through an anterior capsule opening in the natural lens. This anterior opening is created by performing an anterior capsulotomy, preferably an anterior capsulorhexis, on the natural lens and is circumferentially surrounded by an anterior capsular rim which is the remnant of the anterior capsule of the natural lens. The improved accommodating intraocular lens includes a central optic having normally anterior and posterior sides and two plate haptics joined to and extending generally radially out from diametrically opposite edges of the optic. These haptics have a width less than the diameter of the optic and are longitudinally tapered so as to diminish in width toward the outer ends of the haptics. The haptics are movable anteriorly and posteriorly relative to the optic and to this end are either hinged at their inner ends to the optic or are resiliently bendable through their length. In this regard, it is important to note at the outset that in this disclosure, the terms "flex", "flexing", "flexible", and the like, as applied to the lens haptics, are used in a broad sense to cover both hinged and resiliently bendable haptics.

The plate haptics of the preferred intraocular lens of the invention are generally T-shaped haptics each having a haptic plate proper and a pair of relatively slender resiliently flexible fingers at the

outer end of the haptic plate. In their normal unstressed state, the two fingers at the outer end of each haptic extend laterally from opposite edges of the respective haptic plate in the plane of the haptic plate and substantially flush with the radially outer end edge of the haptic plate to form the horizontal "crossbar" of the haptic T-shape.

The lens is implanted within the evacuated capsular bag of the eye through the anterior capsule opening in the bag and in a position wherein the lens optic is aligned with the opening, and the outer T-ends of the lens haptics are situated within the outer perimeter or cul-de-sac of the bag. The lens has a radial length from the outer end of one haptic plate to the outer end of the other haptic plate such that when the lens is thus implanted within the capsular bag, the outer ends of haptics engage the inner perimetrical wall of the bag without stretching the bag.

The preferred accommodating lens of the invention has haptic plates whose radially outer end edges are circularly curved about the central axis of the lens optic to substantially equal radii closely approximating the radius of the interior perimeter of the capsular bag when the ciliary muscle of the eye is relaxed. During implantation of the lens in the bag, the inner perimetrical wall of the bag deflects the

haptic fingers generally radially inward from their normal unstressed positions to arcuate bent configurations in which the radially outer edges of the fingers and the curved outer end edges of the respective haptic plates conform approximately to a common circular curvature closely approximating the curvature of the inner perimetrical wall of the bag. The outer T-ends of the haptics, that is the outer ends of the haptic plates and the haptic fingers, then press lightly against the perimetrical bag wall to accurately center the implanted lens in the bag with the lens optic aligned with the anterior capsule opening in the bag.

After surgical implantation of the accommodating ectodermal lens in the capsular bag of the eye, active endodermal cells on the posterior side of the anterior capsule rim of the bag cause fusion of the rim to the elastic posterior capsule of the bag by fibrosis. This fibrosis occurs about the lens haptics in such a way that the haptics are effectively "shrink-wrapped" by the capsular bag to fixate the outer T-ends of the haptics in the outer cul-de-sac of the bag and form radial haptic pockets which contain the portions of the haptic plates between the haptic fingers and the optic. The lens is thereby fixated in its centered position within the capsular bag. The anterior capsule rim

shrinks during such fibrosis, and this shrinkage of the anterior capsule rim combined with shrink-wrapping of the haptics causes some endwise compression of the lens in a manner which tends to move the lens optic relative to the fixated outer haptic ends in one direction or the other along the axis of the optic. The fibrosed, leather-like anterior capsule rim prevents anterior movement of the optic. Accordingly, fibrosis induced movement of the optic occurs posteriorly to a distant vision position in which the optic presses rearwardly against the elastic posterior capsule of the capsular bag and stretches this posterior capsule rearwardly.

During surgery, the ciliary muscle of the eye is paralyzed with a ciliary muscle relaxant, i.e., a cycloplegic, to place the muscle in its relaxed state. Following surgery, a ciliary muscle relaxant is periodically introduced into the eye throughout a post-operative fibrosis and healing period (from two to three weeks) to maintain the ciliary muscle in its relaxed state until fibrosis is complete. This drug-induced relaxation of the ciliary muscle prevents contraction of the muscle and immobilizes the capsular bag during fibrosis. By this means, the lens optic is fixed in its distant vision position within the eye relative to the retina wherein the lens optic presses rearwardly against and thereby posteriorly stretches

the elastic posterior capsule of the capsular bag. If the ciliary muscle were not thus maintained in its relaxed state until the completion of fibrosis, the muscle would undergo essentially normal brain-induced vision accommodation contraction and relaxation during fibrosis. This ciliary muscle action during fibrosis would result in improper formation of the haptic pockets in the fibrosis tissue. Moreover, ciliary muscle contraction during fibrosis would compress the capsular bag radially and the lens endwise in such a way as to very likely dislocate the lens from its proper position in the bag.

When the cycloplegic effect of the ciliary muscle relaxant wears off after the completion of fibrosis, the ciliary muscle again becomes free to undergo normal brain-induced contraction and relaxation. Normal brain-induced contraction of the muscle then compresses the lens endwise, relaxes the anterior capsule rim, and increases vitreous pressure in the vitreous chamber of the eye. This normal contraction of the ciliary muscle effects anterior accommodation movement of the lens optic for near vision by the combined action of the increased vitreous pressure, lens compression, anterior capsule rim relaxation, and the anterior bias of the stretched posterior capsule. Similarly, brain-induced relaxation of the ciliary muscle reduces

vitreous pressure, relieves endwise compression of the lens, and stretches the anterior capsule rim to effect posterior movement of the lens optic for distant vision by the stretched anterior capsule rim.

Normal brain-induced relaxation and contraction of the ciliary muscle after the completion of fibrosis thus causes anterior and posterior accommodation movement of the lens optic between near and distant vision positions relative to the retina. During this accommodation movement of the optic, the lens haptic plates undergo endwise movement within their pockets in the fibrosed capsular tissue. Primary advantages of the improved accommodating intraocular lens of this invention reside in the fact that the relatively narrow haptic plates of the T-shaped haptics flex relatively easily to aid the accommodating action of the lens and form haptic pockets of maximum length in the fibrose tissue between the haptic fingers and the optic which maximize the accommodation movement of the lens optic. The tapered plate haptics, being wider adjacent to the optic, can slide radially in the capsular bag pockets during contraction of the ciliary muscle, thereby causing the optic to move forward to produce accommodation.

In another important embodiment, the haptics are thickened and contoured. Upon contraction of the

ciliary muscles and the resultant endwise compression of the lens, the contoured haptics slide relative to the posterior capsule to provide enhanced, increased anterior movement of the optic for accommodation.

Brief Description of Drawings

Figure 1 is an anterior face view of a preferred improved accommodating intraocular lens according to the invention showing the lens in its normal unstressed state;

Figure 2 is an edge view of the improved lens in Figure 1 looking in the direction of the arrow 2 in Figure 1 and showing the hinging action of the lens haptics in broken lines;

Figure 3 is a section taken through a human eye having the improved accommodating intraocular lens of Figures 1 and 2 implanted within a natural capsular bag in the eye;

Figure 4 is an enlarged view taken on line 4-4 in Figure 3 with portions broken away for clarity;

Figure 5 is an enlarged fragmentary section similar to the anterior portion of Figure 1 illustrating the initial placement of the lens in the eye;

Figures 6-8 are sections similar to Figure 5 illustrating the normal vision-accommodating action of

the accommodating lens;

Figure 9 is an anterior face view of a modified accommodating intraocular lens according to the invention;

Figure 10 is an edge view of the lens in Figure 9 illustrating the flexibility of the lens haptics;

Figure 11 is an anterior face view of a modified accommodating intraocular lens according to the invention wherein three haptics are utilized;

Figure 12 is an enlarged partial section, similar to the anterior portion of Figure 3, illustrating an embodiment of the invention wherein thickened, curved haptics are utilized;

Figure 13 is a fragmentary sectional view similar to a portion of Figure 12, showing the lens of Figure 12 after fibrosis of haptic end portions;

Figure 14 is a view similar to that of Figure 11, but showing the lens positioned for mid-range vision; and

Figure 15 is a view similar to those of Figures 13 and 14, but showing the lens positioned to accommodate near vision.

Best Mode for Carrying Out the Invention

Turning now to these drawings, and first to Figure 3, there is illustrated a human eye 10 whose natural

crystalline lens matrix has been removed from the natural lens capsule of the eye through an anterior opening in the capsule formed by an anterior capsulotomy, in this case a continuous tear circular capsulotomy, or capsulorhexis. As noted earlier, this natural lens matrix, which is normally optically clear, often becomes cloudy and forms a cataract which is cured by removing the matrix and replacing it with an artificial intraocular lens.

As mentioned earlier, continuous tear circular capsulotomy, or capsulorhexis, involves tearing the anterior capsule along a generally circular tear line in such a way as to form a relatively smooth-edged circular opening in the center of the anterior capsule. The cataract is removed from the natural lens capsule through this opening. After completion of this surgical procedure, the eye includes an optically clear anterior cornea 12, an opaque sclera 14 on the inner side of which is the retina 16 of the eye, an iris 18, a capsular bag 20 behind the iris, and a vitreous cavity 21 behind the capsular bag filled with the gel-like vitreous humor. The capsular bag 20 is the structure of the natural lens of the eye which remains intact within the eye after the continuous tear circular tear capsulorhexis has been performed and the natural lens matrix has been removed from the natural

lens.

The capsular bag 20 includes an annular anterior capsular remnant or rim 22 and an elastic posterior capsule 24 which are joined along the perimeter of the bag to form an annular crevice-like cul-de-sac 25 (Fig. 5) between rim and posterior capsule. The capsular rim 22 is the remnant of the anterior capsule of the natural lens which remains after capsulorhexis has been performed on the natural lens. This rim circumferentially surrounds a central, generally round anterior opening 26 (capsulotomy) in the capsular bag through which the natural lens matrix was previously removed from the natural lens. The capsular bag 20 is secured about its perimeter to the ciliary muscle 28 of the eye by zonules 30.

Natural accommodation in a normal human eye having a normal human crystalline lens involves automatic contraction or constriction and relaxation of the ciliary muscle of the eye by the brain in response to looking at objects at different distances. Ciliary muscle relaxation, which is the normal state of the muscle, shapes the human crystalline lens for distant vision. Ciliary muscle contraction shapes the human crystalline lens for near vision. The brain-induced change from distant vision to near vision is referred to as accommodation.

Implanted within the capsular bag 20 of the eye 10 is an accommodating intraocular lens 32 according to this invention which replaces and performs the accommodation function of the removed human crystalline lens. The accommodating intraocular lens may be utilized to replace either a natural lens which is virtually totally defective, such as a cataractous natural lens, or a natural lens that provides satisfactory vision at one distance without the wearing of glasses but provides satisfactory vision at another distance only when glasses are worn. For example, the accommodating intraocular lens of the invention can be utilized to correct refractive errors and restore accommodation for persons in their mid-40s who require reading glasses or bifocals for near vision.

Intraocular lens 32 comprises a unitary body which may be formed of relatively hard material, relatively soft flexible semi-rigid material, or a combination of both hard and soft materials. Examples of relatively hard materials which are suitable for the lens body are methyl methacrylate, polysulfones, and other relatively hard biologically inert optical materials. Examples of suitable relatively soft materials for the lens body are silicone, hydrogels, thermolabile materials, and other flexible semi-rigid biologically inert optical materials.

The lens 32 includes a central optic 34 and T-shaped plate haptics 36 extending from diametrically opposite edges of the optic. These haptics include haptic plates 36a proper having inner ends joined to the optic and opposite outer free ends and lateral fingers 36b at their outer ends. The haptic plates 36a are longitudinally tapered so as to narrow in width toward their outer ends and have a width throughout their length less than the diameter of the optic 34. The haptics 36 are movable anteriorly and posteriorly relative to the optic 34, that is to say the outer ends of the haptics are movable anteriorly and posteriorly relative to the optic. The preferred lens embodiment illustrated is constructed of a resilient semi-rigid material and has flexible hinges 38 which join the inner ends of the haptic plates 36a to the optic. The haptics are relatively rigid and are flexible about the hinges anteriorly and posteriorly relative to the optic as shown in Figure 2. These hinges are formed by grooves 40 which enter the anterior sides and extend across the inner ends of the haptic plates 36a. The haptics 36 are flexible about the hinges 38 in the anterior and posterior directions of the optic. The lens has a relatively flat unstressed configuration, illustrated in Figure 3, wherein the haptics 36 and their hinges 38 are disposed in a common plane

transverse to the optic axis of the optic 34. Deformation of the lens from this normal unstressed configuration by anterior or posterior deflection of the haptics about their hinges creates in the hinges elastic strain energy forces which urge the lens to its normal unstressed configuration. The outer end edges 41 of the haptic plates 36a are preferably circularly curved to equal radii about the optic axis of the optic 34, as shown in Figure 1. In their normal unstressed state shown in solid lines in Figure 1, the fingers 36b of each plate haptic 36 extend laterally out from opposite longitudinal edges of the respective haptic plate 36a in the plane of the plate and substantially flush with the outer end edge 41 of the plate. When unstressed, the fingers 36b are preferably bowed with a slight radially inward curvature, as shown in solid lines in Figure 1. As shown in broken lines in Figure 1, the fingers 36b are laterally resiliently flexible radially of the haptic plates 36a to their broken line positions of Figure 1 in which the radially outer edges of the fingers and the end edges 41 of the haptic plates 36a conform substantially to a common circle centered on the axis of the optic 34.

The accommodating intraocular lens 32 is implanted within the capsular bag 20 of the eye 10 in the position shown in Figures 4 and 5. When implanting the

lens in the eye, the ciliary muscle 28 of the eye is paralyzed in its relaxed state, shown in Figure 5, in which this muscle stretches the capsular bag 20 to its maximum diameter. The lens is inserted into the bag through the anterior capsule opening 26 and is sized in length, endwise of the haptics 36, for placement of the lens in the position shown in Figures 4 and 5. In this position, the lens optic 34 is aligned with anterior opening 26 in the bag, as shown in Figure 4. The posterior side of the lens faces the elastic posterior capsule 24 of the capsular bag, and the posterior side of the lens optic 34 is disposed in close proximity to or contacts the posterior capsule. The radially outer T-ends of the lens haptics 36 are positioned within the cul-de-sac 25 of the capsular bag with the outer end edges 41 of the haptic plates 36a and the haptic fingers 36b in close proximity to or seating lightly against the capsular bag cul-de-sac wall. This cul-de-sac wall deflects the haptic fingers inwardly to the positions shown in broken lines in Figure 4 (which approximate the broken line finger positions shown in Figure 1). In these deflected positions, the end edges 41 of the haptic plates and the haptic fingers 36b conform closely to the curvature of the cul-de-sac wall to accurately center the lens in the capsular bag. The lens is thus sized and shaped so that when the ciliary

muscle 28 is paralyzed in its relaxed state, the lens fits in the capsular bag 20 with a sufficiently close fit to accurately align the lens optic 34 with the anterior capsule opening 26 in the bag without significantly deforming the bag.

The actual dimensions of an intraocular lens according to this invention will be determined by each patient's ocular dimensions. Following are the dimensions of a typical accommodating intraocular lens according to the invention:

Diameter of optic 34----------------------------4.50 mm
Inner end width of haptic plates 36a------------1.5 mm
Outer end width of haptic plates 36a------------1.3 mm
Outer end radius of haptic plates 36a-----------5.25 mm
Haptic finger thickness-------------------------0.12 mm
Distance between unstressed haptic finger tips--4.5 mm
Longitudinal distance between unstressed haptic
  finger tips----------------------------------11.5 mm

During a post-operative fibrosis and healing period on the order of two to three weeks following surgical implantation of the lens 32 in the capsular bag 20, epithelial cells under the anterior capsular rim 22 of the bag cause fusion of the rim to the posterior capsule 24 by fibrosis. This fibrosis occurs around the lens haptics 36 in such a way that the haptics are "shrink-wrapped" by the capsular bag 20,

and the haptics form pockets 42 in the fibrosed material 43. These pockets cooperate with the lens haptics to position and center the lens in the eye. In order to insure proper formation of the haptic pockets 42 and prevent dislocation of the lens by ciliary muscle contraction during fibrosis, sufficient time must be allowed for fibrosis to occur to completion without contraction of the ciliary muscle 28 from its relaxed state of Figure 5. This is accomplished by introducing a ciliary muscle relaxant (cycloplegic) into the eye before surgery to dilate the pupil and paralyze the ciliary muscle in its relaxed state and having the patient periodically administer cycloplegic drops into the eye during a post-operative period of sufficient duration (two to three weeks) to permit fibrosis to proceed to completion without contraction of the ciliary muscle. The cycloplegic maintains the ciliary muscle 28 in its relaxed state in which the capsular bag 20 is stretched to its maximum diameter (Fig. 5) and immobilized, and the anterior capsular rim 22 is stretched to a taut trampoline-like condition or position. The rim fibroses from this taut condition. The cycloplegic passes through the cornea of the eye into the fluid within the eye and then enters the ciliary muscle from this fluid. While other cycloplegics may be used, atropine is the preferred

cycloplegic because of its prolonged paralyzing effect compared to other cycloplegics. One drop of atropine, for example, may last for two weeks. However, to be on the safe side, patients may be advised to place one drop of atropine in the eye every day during the fibrosis period.

The capsular rim 22 shrinks during fibrosis and thereby shrinks the capsular bag 20 slightly in its radial direction. This shrinkage combines with shrink wrapping of the lens haptics 36 produces some opposing endwise compression of the lens which tends to buckle or flex the lens at its hinges 38 and thereby move the lens optic 34 along the axis of the eye. Unless restrained, this flexing of the lens might occur either forwardly or rearwardly. The taut anterior capsular rim 22 pushes rearwardly against and thereby prevents forward flexing of the lens. This fibrosis-induced compression of the lens is not sufficient to interfere with proper formation of the haptic pockets in the fibrosed tissue or cause dislocation of the lens. Accordingly, endwise compression of the lens by fibrosis aided by the rearward thrust of the taut capsular rim against the lens haptics 36 causes rearward flexing of the lens from its initial position of Figure 5 to its position of Figure 6. The lens haptics 36 are made sufficiently rigid that they will

not buckle under the forces of fibrosis. At the conclusion of fibrosis, the lens occupies its posterior position of Figure 6 wherein the lens presses rearwardly against the elastic posterior capsule 24 and stretches this capsule rearwardly. The posterior capsule then exerts a forward elastic bias force on the lens. This posterior position of the lens is its distant vision position.

Natural accommodation in a normal human eye involves shaping of the natural crystalline lens by automatic contraction and relaxation of the ciliary muscle of the eye by the brain to focus the eye at different distances. Ciliary muscle relaxation shapes the natural lens for distant vision. Ciliary muscle contraction shapes the natural lens for near vision.

The accommodating intraocular lens 32 is uniquely constructed to utilize this same ciliary muscle action, the fibrosed capsular rim 22, the elastic posterior capsule 24, and the vitreous pressure within the vitreous cavity 21 to effect accommodation movement of the lens optic 34 along the optic axis of the eye between its distant vision position of Figure 6 to its near vision position of Figure 8. Thus, when looking at a distant scene, the brain relaxes the ciliary muscles 28. Relaxation of the ciliary muscle stretches the capsular bag 20 to its maximum diameter and its

fibrosed anterior rim 22 to the taut trampoline-like condition or position discussed above. The taut rim deflects the lens rearwardly to its posterior distant vision position of Figure 6 in which the elastic posterior capsule 24 is stretched rearwardly relative to the general plane of the fibrosed haptic end portions, by the lens and thereby exerts a forward bias force on the lens. When looking at a near scene, such as a book when reading, the brain constricts or contracts the ciliary muscle. This ciliary muscle contraction has the three-fold effect of increasing the vitreous cavity pressure, relaxing the capsular bag 20 and particularly its fibrosed capsular rim 22, and exerting opposing endwise compression forces on the ends of the lens haptics 36 with resultant endwise compression of the lens. Relaxation of the capsular rim permits the rim to flex forwardly and thereby enables the combined forward bias force exerted on the lens by the rearwardly stretched posterior capsule and the increased vitreous cavity pressure to push the lens forwardly relative to the general plane of the fibrosed haptic end portions, in an initial accommodation movement from the position of Figure 6 to the intermediate accommodation position of Figure 7.

In this intermediate accommodation position, the lens is substantially flat, and the ends of the lens

haptics and their hinges 38 are disposed substantially in a common plane normal to the axis of the eye. Prior to accommodation, the lens arches rearwardly so that endwise compression of the lens by ciliary muscle contraction tends to produce a rearward buckling force on the lens. However, the increased vitreous cavity pressure and the forward bias force of the stretched posterior capsule are sufficient to overcome this opposing rearward buckling force and effect forward accommodation movement of the lens to and at least just slightly beyond the intermediate position of Figure 7. At this point, endwise compression of the lens by the contracted ciliary muscle produces a forward flexing force on the lens which effects final accommodation of the lens beyond the intermediate position of Figure 7 to the near vision position of Figure 8. Subsequent brain-induced relaxation of the ciliary muscle 28 in response to looking at a distant scene reduces the vitreous cavity pressure, stretches the capsular bag 20 to its maximum diameter, and restores the anterior capsular rim 22 to its taut trampoline-like condition to effect return of the lens to its distant viewing position of Figure 6. During accommodation, the lens optic 34 moves along the axis of the eye in the direction towards the retina 16. The effective power of the optic is selected by the brain to sharply focus

incoming light by moving the optic along the axis of the eye by contraction and relaxation of the ciliary muscle.

The lens haptics 36 flex at their hinges 38 with respect to the lens optic 34 during accommodation. Any elastic strain energy forces developed in the hinges during this flexing produces additional anterior and/or posterior forces on the lens. For example, assume that the lens is relatively flat, i.e., that the lens haptics 36 lie in a common plane as shown in Figure 1, in the normal unstressed state of the lens. In this case, posterior deflection of the lens from its position of Figure 1 to its distant vision position of Figure 6 creates elastic strain energy forces in the hinges 38 which urge the lens forwardly back to its unstressed position of Figure 1 and thus aid the above discussed initial accommodation of the lens in response to contraction of the ciliary muscle. Final accommodation flexing of the lens from its intermediate position of Figure 7 to its near vision position of Figure 8 creates elastic strain energy forces in the hinges 38 which urge the lens rearwardly toward its unstressed position and thus aid initial return of the lens from its near vision position to its distant vision position in response to relaxation of the ciliary muscle. The lens may be designed to assume

some other normal unstressed position, of course, in which case any elastic strain energy forces created in the lens during flexing of the haptics will aid, resist, or both aid and resist accommodation of the lens to its near vision position and return of the lens to its distant vision position depending upon the unstressed position of the lens.

During accommodation, the lens haptic plates 36a slide endwise in their fibrosed tissue pockets 42. As shown best in Figures 1, 2 and 4, the haptics are tapered endwise in width and thickness to enable the haptics to move freely in the pockets. The lens optic 34 moves toward and away from the anterior capsular rim 22. The diameter of the optic is made as large as possible to maximize its optical imaging efficiency. The optic is preferably but not necessarily made smaller than the diameter of the anterior capsule opening 26 to permit accommodation movement of the optic into and from the opening without interference by the capsular rim 22 in order to maximize the accommodation range.

The modified accommodating intraocular lens 100 shown in Figures 9 and 10 is identical to the lens 32 shown in Figures 1-8 except as noted below. Thus the modified lens has an optic 102 and generally T-shaped haptics 104 extending radially out from diametrically

opposite edges of the optic. These haptics include longitudinally tapered haptic plates 106 and flexible haptic fingers 108 at the outer ends of these plates extending laterally out from the longitudinal edges of the plates. The modified lens 100 differs from the lens 32 only in that the haptic hinges 38 and hinge grooves 40 of the lens 32 are omitted in the modified lens 100, and the haptic plates 106 of the modified lens are made resiliently flexible or bendable throughout their length, as indicated in broken lines in Figure 10. The modified lens is implanted in a capsular bag of a human eye and provides vision accommodation in response to ciliary muscle contraction and relaxation in the same manner as described in connection with the lens 32.

The accommodating intraocular lens 110 of Figure 11 differs from the earlier-described lenses, in that it embodies an optic 112 from which extend three haptics 36a extending radially outward. Haptic 36a includes a longitudinally tapered haptic plate 114 and flexible haptic fingers 36b. Although three haptics are shown, it will be understood that four or even more haptics can be provided. Like the lenses earlier described, the lens 110 is implanted in the capsular bag of an eye and provides vision accommodation with response to ciliary muscle contraction and relaxation.

The arrangement of the three or more haptics serves to provide improved centration of the lens and optic relative to the eye, and of the optic relative to the opening in the anterior capsule of the capsular bag.

The accommodating intraocular lens 200 of Figures 12-15 differs from the lens of Figures 1-8, in that the haptics 202 increase in thickness from their outer ends and toward their junctures with the optic 204. The thickened portions of the haptics have curved surfaces 206, and are joined to the optic by flexible portion or hinge portions 208.

In the operation of the lens 200 in effecting accommodation, the curved surfaces 206 of the haptics engage the posterior capsule 20. After fibrosis around the end portions of the haptics, the haptics and optic are positioned as generally indicated in Figure 13, for distance vision. The thickness and proportions of the haptics space the optic from the posterior capsule to define a space between the optic 204 and posterior capsule 20. Therefore, vitreous fluid pressure exerts force on the haptics 202 and not on the optic 204 when the vitreous begins to push anteriorly. The vitreous pressure does not exert force on the optic, as with the embodiments earlier described, but exert forces on the haptics 202, as indicated by arrows V in Figure 13. The optic being spaced from the anterior capsular bag,

the first anteriorly directed force is not exerted on the optic. Contraction of the ciliary muscles 30 first produces an increase in pressure in the vitreous cavity which initiates the anterior movement of the haptics and optic. The anterior movement is continued when the optic is anterior to the haptic, by compressive, end-to-end pressure on the lens 20, which effects sliding of curved surfaces 206 of the haptics relative to the tightened posterior capsule, thus to move the optic further anteriorly beyond the plane of the haptic end portions, which are encapsulated between the fibrosed anterior capsular rim and the posterior capsule. Further anterior movement of the optic is provided than is provided by the lens embodiments earlier described, and the optic may be positioned further anteriorly for accommodation of near vision, as indicated in Figure 15. Figure 13 illustrates the positioning of the lens by ciliary muscle action for distant vision. When the ciliary muscle relaxes, it pulls the haptic fingers peripherally, the fingers being encapsulated in the fibrosed periphery of the capsular bag. Figure 14 shows the positioning of the lens for mid-range accommodation.

Claims

1. An accommodating intraocular lens comprising:

a lens body having normally anterior and posterior sides and including an optic and plate haptics at opposite sides of the optic, and wherein

said plate haptics include haptic plates extending generally radially out from the optic and having flexible inner end portions joined to edge portions of said optic and opposite outer ends, and

said haptic plates have a width throughout their length substantially less than the diameter of said optic and are flexible adjacent to the optic anteriorly and posteriorly relative to said optic, whereby said optic is movable anteriorly and posteriorly relative to the plane of the outer ends of said haptic plates.

2. An accommodating intraocular lens according to Claim 1, wherein:

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

3. An accommodating intraocular lens according to Claim 1, wherein:

the inner ends of said haptic plates are pivotably hinged relative to said optic, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

4. An accommodating intraocular lens according to Claim 1, wherein:

the inner end portions of said haptic plates are relatively thin, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

5. An accommodating intraocular lens according to Claim 1, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

the inner ends of said haptic plates are joined to said optic by reduced thickness resiliently flexible hinge portions, whereby said haptic plates are resiliently pivotally movable about said hinge portions anteriorly and posteriorly relative to said optic, and compression and relaxation of said lens body endwise of said haptic plates effects anterior and

posterior movement of said optic relative to the outer ends of said haptic plates.

6. An accommodating intraocular lens according to Claim 1, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

7. An accommodating intraocular lens according to Claim 1, wherein:

said haptic plates have longitudinal edges,

said plate haptics are generally T-shaped and include a pair of relatively slender resiliently flexible fingers at the outer end of each haptic plate extending from the longitudinal edges, respectively, of the respective haptic plate in the plane of the respective haptic plate and substantially flush with the outer end of the respective haptic plate, and

said fingers have normal unstressed states in which the fingers extend generally transverse to the length of the haptic plates.

8. An accommodating intraocular lens according to Claim 1, wherein:

said optic has an optic axis,

said plate haptics are generally T-shaped and include a pair of relatively slender resiliently flexible fingers at the outer end of each haptic plate.

said haptic plates have longitudinal edges and outer end edges and are longitudinally tapered so as to narrow toward said outer end edges,

said outer end edges are generally circularly curved to substantially equal radii about said optic axis,

said fingers extend from the longitudinal edges, respectively, of each haptic plate in the plane of the respective haptic plate and substantially flush with the outer end edge of the respective haptic plate, and

said fingers have normal unstressed states in which the fingers extend generally transverse to the length of the haptic plates, and said fingers are resiliently flexible inwardly toward said optic to positions in which said outer end edges of said haptic plates and said fingers conform approximately to a common circle centered on said optic axis.

9. An accommodating intraocular lens according to Claim 8, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends,

the inner ends of said haptic plates are resiliently pivotally hinged to said optic, whereby said haptic plates are resiliently pivotally movable anteriorly and posteriorly relative to said optic.

10. An accommodating intraocular lens according to Claim 8, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends,

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

11. An accommodating intraocular lens comprising:

a lens body having normally anterior and posterior sides and including an optic and generally T-shaped plate haptics at diametrically opposite sides of the optic, and wherein,

said plate haptics include haptic plates extending generally radially out from said optic

and having inner ends joined to diametrically opposite edge portions of said optic and opposite outer ends, and a pair of relatively slender flexible fingers at the outer end of each haptic plate,

said haptic plates have longitudinal edges, and said fingers of each plate haptic extend from the longitudinal edges, respectively, of the respective haptic plate in the plane of the respective haptic plate and substantially flush with the outer end of the respective haptic plate, and

said fingers have normal unstressed states in which the fingers extend generally transverse to the length of the haptic plates, and said fingers are resiliently flexible inwardly toward said optic.

12. An accommodating intraocular lens according to Claim 11, wherein:

said optic has an optic axis,

said haptic plates have arcuate outer end edges which are substantially circularly curved to approximately equal radii about said axis, and

said fingers are flexible toward said optic to positions wherein said outer haptic plate edges

and said fingers conform approximately to a common circle centered on said axis.

13. An accommodating intraocular lens according to Claim 11, wherein:

said haptic plates are substantially narrower in width throughout their length than the diameter of said optic.

14. An accommodating intraocular lens according to Claim 11, wherein:

the inner ends of said haptic plates are resiliently pivotally hinged to said optic, whereby said haptic plates are resiliently pivotally movable anteriorly and posteriorly relative to said optic.

15. An accommodating intraocular lens according to Claim 11, wherein:

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

16. An accommodating intraocular lens according to Claim 14, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer end and have a width throughout their length substantially less than the diameter of said optic.

17. An accommodating intraocular lens according to Claim 15, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer end and have a width throughout their length substantially less than the diameter of said optic.

18. An accommodating intraocular lens according to Claim 1, wherein:

said lens is adapted to be implanted in a human eye within a natural capsular bag in the eye attached about its perimeter to the ciliary muscle of the eye and including an elastic posterior capsule which is urged anteriorly by vitreous pressure in the eye and an anterior capsule opening bounded circumferentially by an anterior capsule remnant that fuses to the posterior capsule by fibrosis during a postoperative fibrosis period in which said bag and remnant shrink, and said remnant being tautly stretched by relaxation of the ciliary muscle and relaxed by

contraction of the ciliary muscle after fibrosis is complete, and

said lens is adapted to be implanted in said bag while said ciliary muscle is in its relaxed state and in an implanted position wherein said optic is aligned with said anterior capsule opening and said plate haptics are disposed between said posterior capsule and said anterior capsule remnant, whereby said fibrosis occurs about the plate haptics and said optic is urged posteriorly against said posterior capsule during fibrosis, and after fibrosis is complete, relaxation of the ciliary muscle effects posterior movement of said optic to a distant vision position and contraction of the ciliary muscle effects anterior accommodation movement of the optic.

19. An accommodating intraocular lens according to Claim 11, wherein:

said lens is adapted to be implanted in a human eye within a natural capsular bag in the eye attached about its perimeter to the ciliary muscle of the eye and including an elastic posterior capsule which is urged anteriorly by vitreous pressure in the eye and an anterior capsule

opening bounded circumferentially by an anterior capsule remnant which forms an annular cul-de-sac about the inner perimeter of said bag and fuses to the posterior capsule by fibrosis during a post-operative fibrosis period during which said bag and remnant shrink, and said remnant being tautly stretched by relaxation of the ciliary muscle and relaxed by contraction of the ciliary muscle after fibrosis is complete, and

said lens is adapted to be implanted in said bag while said ciliary muscle is in its relaxed state and in an implanted position wherein said optic is aligned with said anterior capsule opening, said plate haptics are disposed between said posterior capsule and said anterior capsule remnant with said haptic fingers and said outer haptic ends positioned within said cul-de-sac in close proximity to the inner perimeter of the bag, and said haptic fingers are bent inwardly toward the optic to conform to the inner perimeter of the bag, whereby said fibrosis occurs about said haptic plates and said haptic fingers and said optic is urged posteriorly against said posterior capsule during fibrosis, and after fibrosis is complete, relaxation of the ciliary muscle effects posterior movement of said optic to a distant

vision position and contraction of the ciliary muscle effects anterior accommodation movement of the optic.

20. A method of implanting an intraocular lens within a natural capsular bag of a patient's eye, said bag being attached about its perimeter to the ciliary muscle of the eye and including an elastic posterior capsule urged anteriorly by vitreous pressure in the eye and an anterior capsule opening bounded circumferentially by an anterior capsule remnant which forms with said posterior capsule an annular cul-de-sac about the inner perimeter of said bag and fuses by fibrosis to the posterior capsule during a post-operative fibrosis period during which said anterior capsule remnant is stretched taut, and wherein said ciliary muscle has a distant vision relaxed state and a near vision contracted state, and said vitreous pressure is reduced and said bag and anterior remnant are stretched by relaxation of said ciliary muscle, and said vitreous pressure is increased and said bag and anterior remnant are relaxed by contraction of said ciliary muscle, said method comprising the steps of:

selecting an accommodating intraocular lens

comprising a lens body having normally anterior and posterior sides and including an optic and plate haptics at diametrically opposite sides of the optic, and wherein said plate haptics include haptic plates extending generally radially out from the optic and having inner ends joined to diametrically opposite edge portions of said optic and opposite outer ends, and said haptic plates have a width throughout their length substantially less than the diameter of said optic and are flexible anteriorly and posteriorly relative to said optic, whereby said optic is movable anteriorly and posteriorly relative to the outer ends of said haptic plates,

implanting said selected lens within said capsular bag in a position wherein said optic is aligned with said anterior capsule opening and said haptic plates are situated within said cul-de-sac between said anterior capsule remnant and said posterior capsule, and

permitting fibrosis to occur about said haptic plates while the ciliary muscle is in its relaxed state in such a way as to form haptic pockets in the fibrosis tissue containing said haptic plates and effect posterior movement of said optic against said posterior capsule by the

taut anterior remnant, whereby after fibrosis is complete, relaxation of the ciliary muscle causes posterior movement of said optic against said posterior capsule by said anterior remnant, and contraction of the ciliary muscle causes anterior accommodation movement of said optic by said posterior capsule, vitreous pressure, and endwise compression of the lens haptics.

21. A method according to Claim 20, wherein:

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

22. A method according to Claim 20, wherein:

the inner ends of said haptic plates are pivotally hinged to said optic, whereby said haptic plates are pivotally movable anteriorly and posteriorly relative to said optic.

23. A method according to Claim 20, wherein:

the inner ends of said haptic plates are resiliently pivotally hinged to said optic, whereby said haptic plates are resiliently pivotally movable anteriorly and posteriorly

relative to said optic.

24. A method according to Claim 20, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

the inner ends of said haptic plates are joined to said optic by reduced thickness resiliently flexible hinge portions, whereby said haptic plates are resiliently pivotally movable about said hinge portions anteriorly and posteriorly relative to said optic, and compression and relaxation of said lens body endwise of said haptic plates effects anterior and posterior movement of said optic relative to the outer ends of said haptic plates.

25. A method according to Claim 20, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

26. A method of implanting an intraocular lens within a natural capsular bag of a patient's eye, said

bag being attached about its perimeter to the ciliary muscle of the eye and including an elastic posterior capsule urged anteriorly by vitreous pressure in the eye and an anterior capsule opening bounded circumferentially by an anterior capsule remnant which forms with said posterior capsule an annular cul-de-sac about the inner perimeter of said bag and fuses by fibrosis to the posterior capsule during a postoperative fibrosis period during which said anterior capsule remnant is stretched taut, and wherein said ciliary muscle has a distant vision relaxed state and a near vision contracted state, and said vitreous pressure is reduced and said bag and anterior remnant are stretched by relaxation of said ciliary muscle, and said vitreous pressure is increased and said bag and anterior remnant are relaxed by contraction of said ciliary muscle, said method comprising the steps of:

selecting an accommodating intraocular lens having a lens body with normally anterior and posterior sides and comprising an optic and generally T-shaped plate haptics at diametrically opposite sides of the optic including haptic plates extending generally radially out from the optic and having inner ends joined to

diametrically opposite edge portions of said optic, opposite outer ends, and longitudinal edges extending between said ends, and relatively slender resiliently flexible fingers at the outer ends of said haptic plates, and wherein said haptic plates are flexible anteriorly and posteriorly relative to said optic, and said fingers of each haptic extend from the longitudinal edges, respectively, of the respective haptic plate in the plane of and substantially flush with the outer end of the respective haptic plate,

implanting said selected lens within said capsular bag in a position wherein said optic is aligned with said anterior capsule opening, and said haptic plates and haptic fingers are situated within said cul-de-sac between said anterior capsule remnant and said posterior capsule with the outer ends of the haptic plates and said haptic fingers in close proximity to the inner perimeter of said bag and said haptic fingers deflected inwardly toward said optic to conform substantially to the circumferential curvature of the inner perimeter of said bag, and

permitting fibrosis to occur about said haptic plates and said haptic fingers while the

ciliary muscle is in its relaxed state in such a way as to fixate the outer ends of the haptic plates in said bag, form haptic pockets in the fibrosis tissue containing said haptic plates between said optic and haptic fingers, and effect posterior movement of said optic against said posterior capsule by the taut anterior remnant, whereby after fibrosis is complete, relaxation of the ciliary muscle causes posterior movement of said optic against said posterior capsule by said anterior remnant, and contraction of the ciliary muscle causes anterior accommodation movement of said optic by said posterior capsule, vitreous pressure, and endwise compression of the lens.

27. A method according to Claim 26, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends.

28. A method according to Claim 26, wherein:

said optic has an optic axis,

said haptic plates have outer end edges which are generally circularly curved to substantially equal radii about said optic axis,

said fingers are substantially flush with the outer end edges of their respective haptic plates,

and

said fingers have normal unstressed states in which the fingers extend generally transverse to the length of the haptic plates, and said fingers are deflected inwardly toward said optic by the perimeter of said bag to positions in which said outer end edges of said haptic plates and said fingers conform approximately to the inner circumference of said bag.

29. A method according to Claim 26, wherein:

said haptic plates are substantially narrower in width along their entire length than the diameter of said optic.

30. A method according to Claim 26, wherein:

said haptic plates are resiliently flexible throughout their length, whereby said haptic plates are resiliently bendable anteriorly and posteriorly relative to said optic.

31. A method according to Claim 26, wherein:

the inner ends of said haptic plates are pivotally hinged to said optic, whereby said haptic plates are pivotally movable anteriorly and posteriorly relative to said optic.

32. A method according to Claim 26, wherein:

the inner ends of said haptic plates are resiliently pivotally hinged to said optic, whereby said haptic plates are resiliently pivotally movable anteriorly and posteriorly relative to said optic.

33. A method according to Claim 26, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

the inner ends of said haptic plates are joined to said optic by reduced thickness resiliently flexible hinge portions, whereby said haptic plates are resiliently pivotally movable about said hinge portions anteriorly and posteriorly relative to said optic, and compression and relaxation of said lens body endwise of said haptic plates effects anterior and posterior movement of said optic relative to the outer ends of said haptic plates.

34. A method according to Claim 26, wherein:

said haptic plates are longitudinally tapered so as to narrow toward their outer ends, and

said haptic plates are resiliently flexible throughout their length, whereby said haptic

plates are resiliently bendable anteriorly and posteriorly relative to said optic.

35. An accommodating intraocular lens implant within a human eye having a natural capsular bag attached about its periphery to the ciliary muscle of the eye and including an elastic posterior capsule urged anteriorly by vitreous pressure in the eye and an anterior capsule opening bounded by an anterior capsule remnant fused by fibrose tissue to the posterior capsule, said lens implant comprising:

an accommodating intraocular lens having normally anterior and posterior sides and comprising a central optic and generally T-shaped plate haptics extending from diametrically opposite edge portions of the optic, each haptic including a haptic plate movable anteriorly and posteriorly relative to said optic and having inner ends joined to said edge portions, respectively, opposite outer ends, longitudinal edges extending between said ends, and a width throughout its length substantially less than the diameter of said optic, and relatively slender flexible fingers at the outer end of the respective haptic extending from the longitudinal

edges of the respective haptic plate in the plane of the plate and substantially flush with the outer end of the plate, and wherein

said intraocular lens is situated within said capsular bag in a position wherein said optic is aligned with said anterior capsule opening and said haptics are disposed between said remnant and said posterior capsule with said haptic fingers bent to conform substantially to the circumferential curvature of the inner perimeter of said bag and the outer haptic plate ends and said haptic fingers fixated by said fibrose tissue within the perimeter of the bag and with the portions of said haptic plates between said fingers and optic confined within pockets in said fibrose tissue in a manner such that relaxation of the ciliary muscle effects posterior movement of said optic relative to the outer ends of said haptics and contraction of said ciliary muscle effects anterior accommodation movement of said optic relative to the outer ends of said haptics.

36. An accommodating intraocular lens to be implanted within a human eye having a natural capsular bag attached about its perimeter to the ciliary muscle of the eye and from which the natural lens matrix

has been removed, the bag including an elastic posterior capsule urged anteriorly by vitreous pressure in the eye and an anterior capsulotomy circumferentially surrounded by a capsular remnant having epithelial cells on its posterior side which cause fusion of the remnant to the posterior capsule by fibrosis during a certain postoperative period following implantation of the lens in the eye, said intraocular lens comprising:

a lens body having normally anterior and posterior sides and including an optic and plate haptics which extend from two diametrically opposite edges of said optic and have inner ends joined to the optic and opposite outer ends which are movable anteriorly and posteriorly relative to said optic, and wherein

said intraocular lens is sized to be implanted within said capsular bag when the ciliary muscle is paralyzed in its relaxed state and in a position wherein the outer ends of said haptics are disposed between said capsular remnant and the outer perimeter of said posterior capsule and said optic is aligned with said anterior capsulotomy to permit fibrosis about the haptics of the implanted lens during said post-operative period in such a way that after fibrosis is

complete, relaxation of the ciliary muscle effects posterior movement of the implanted lens and constriction of the ciliary muscle effects anterior accommodation of the implanted lens.

37. An accommodating intraocular lens implant within a human eye having a natural capsular bag attached about its perimeter to the ciliary muscle of the eye and from which the natural lens matrix has been removed, the bag including an elastic posterior capsule urged anteriorly by vitreous pressure and an anterior capsulotomy circumferentially surrounded by a capsular remnant fused by fibrose tissue to the posterior capsule, said lens implant comprising:

an intraocular lens having normally anterior and posterior sides and including a central optic, and haptics extending from opposite edges of the optic and having inner ends joined to the optic and opposite outer ends movable anteriorly and posteriorly relative to said optic, and wherein

said intraocular lens is situated within said capsular bag in a position wherein said optic is aligned with said capsulotomy and the outer ends of said haptics are disposed between said anterior capsule rim and the outer perimeter of said

posterior capsule and confined within pockets in the fibrose tissue in a manner such that relaxation of the ciliary muscle effects posterior deflection of the lens and constriction of the ciliary muscle effects anterior accommodation of the lens.

38. An intraocular implant according to Claim 37, wherein:

relaxation of the ciliary muscle reduces vitreous pressure and stretches said capsular remnant to a relatively taut condition to effect posterior deflection of said lens by the remnant to a distant vision position wherein said lens presses against said posterior capsule and stretches the posterior capsule rearwardly to produce a forward elastic bias force on said lens, and constriction of the ciliary muscle relaxes the capsular remnant and increases vitreous pressure to effect anterior accommodation of the lens by said bias force and vitreous pressure.

39. A lens implant according to Claim 37, wherein:

said lens includes fixation means at the outer ends of said haptics which are firmly anchored in said fibrose tissue to positively

prevent dislocation of the lens in said capsular bag.

40. An accommodating intraocular lens implant within a human eye having a natural capsular bag attached about its perimeter to the ciliary muscle of the eye and from which the natural lens matrix has been removed, the bag including an elastic posterior capsule urged anteriorly by vitreous pressure and an anterior capsule opening circumferentially surrounded by a capsular remnant fused by fibrose tissue to the posterior capsule, said lens implant comprising:

an intraocular lens having normally anterior and posterior sides and including a central optic, and haptics extending from opposite edges of the optic and having inner ends joined to the optic and opposite outer ends movable anteriorly and posteriorly relative to said optic, and wherein

said intraocular lens is situated within said capsular bag in a position wherein said optic is aligned with said anterior opening and the outer ends of said haptics are disposed between said remnant and said posterior capsule and confined within pockets in the fibrose tissue in a manner such that relaxation of the ciliary muscle effects

posterior deflection of the lens and constriction of the ciliary muscle effects anterior accommodation of the lens.

41. A lens implant according to Claim 40, wherein:

said lens optic is sized to pass through said opening during accommodation.

42. An accommodating intraocular lens according to Claim 1, wherein:

two haptic plates are utilized.

43. An accommodating intraocular lens according to Claim 1, wherein:

at least three haptic plates are utilized.

44. An accommodating intraocular lens according to Claim 1, wherein:

the haptics are thickened and contoured to slidably engage the posterior capsular bag to move the optic anteriorly of the haptic end portions by action at the flexible connection between the optic and the haptics.

45. An accommodating intraocular lens according to Claim 44, wherein:

the haptics have curved surfaces confronting the posterior bag for sliding engagement therewith upon contraction of ciliary muscles to move the optic anteriorly for near vision accommodation.

46. An accommodating intraocular lens according to Claim 44, wherein:

upon commencement of accommodation, the first urging by vitreous pressure is against said thickened haptics to urge the optic anteriorly.

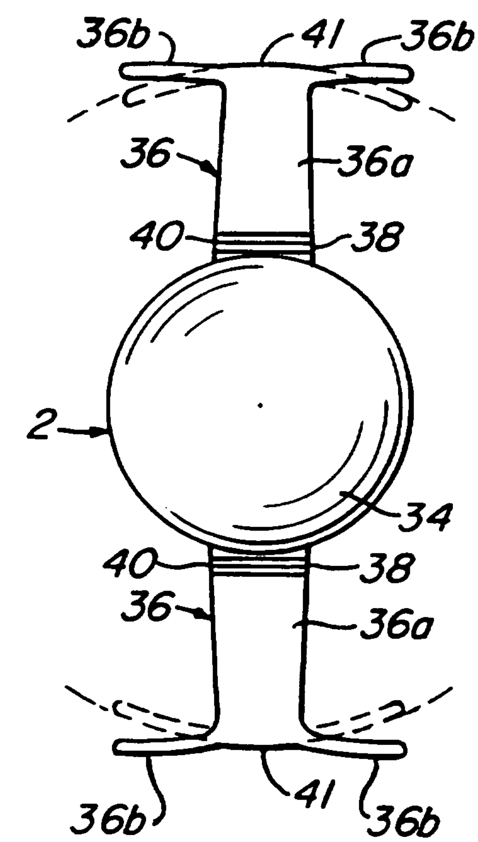

FIG-1

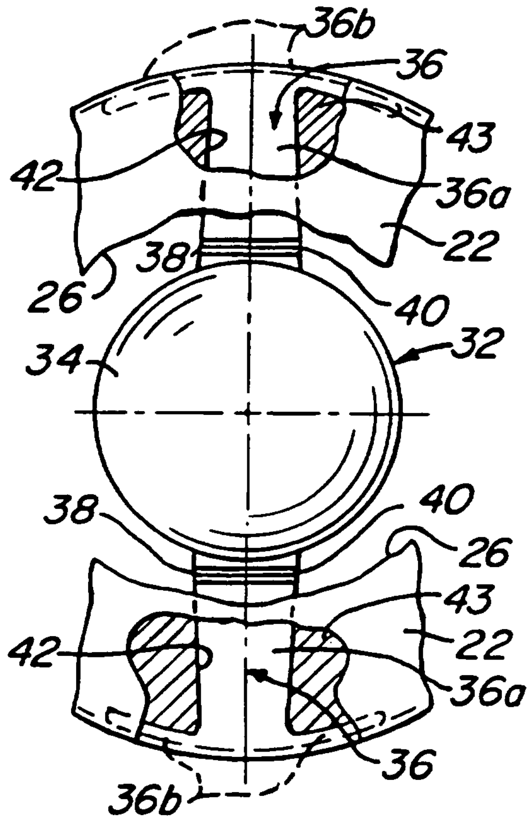

FIG-4

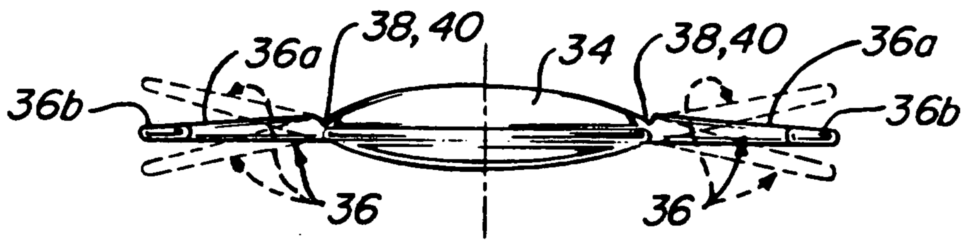

FIG-2

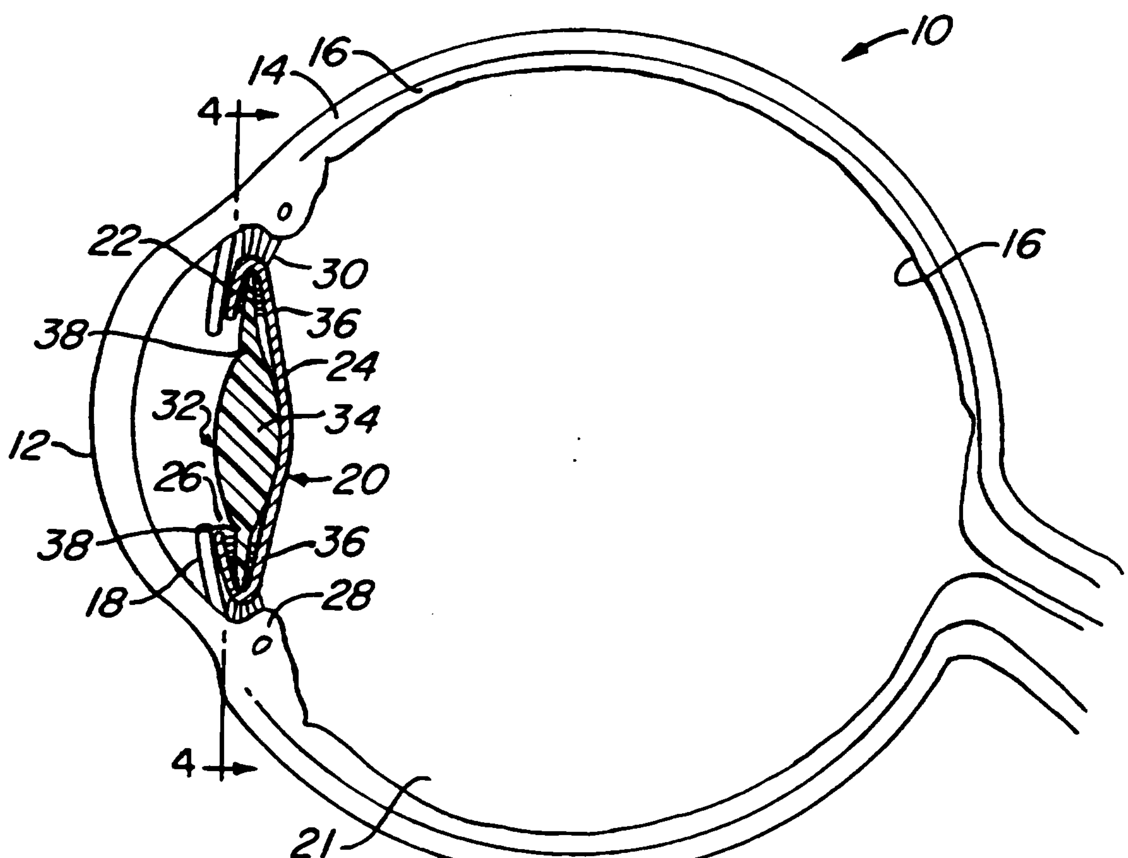

FIG.—3

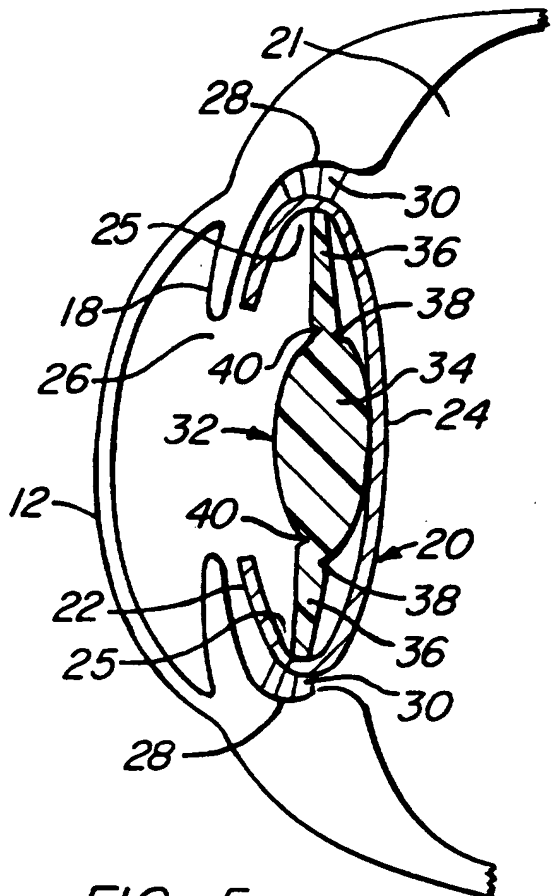

FIG.—5

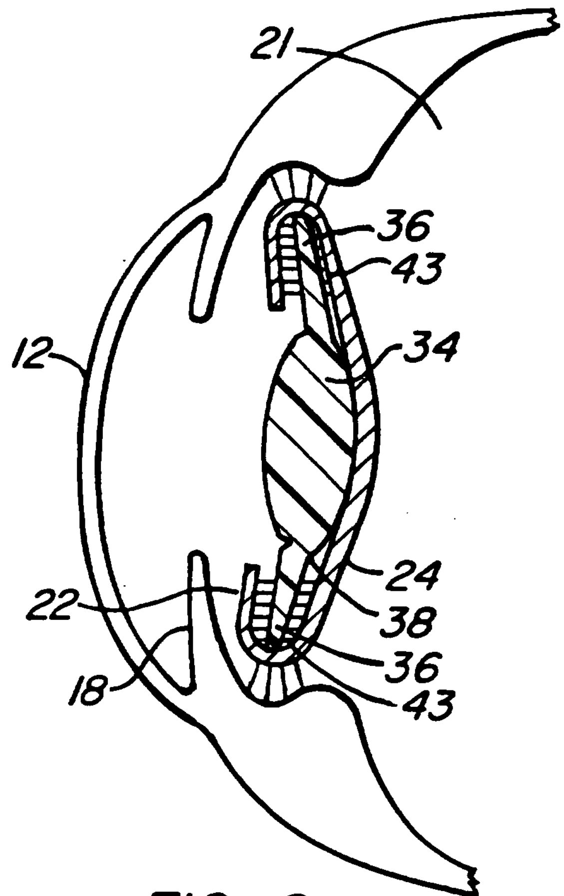

FIG.—6

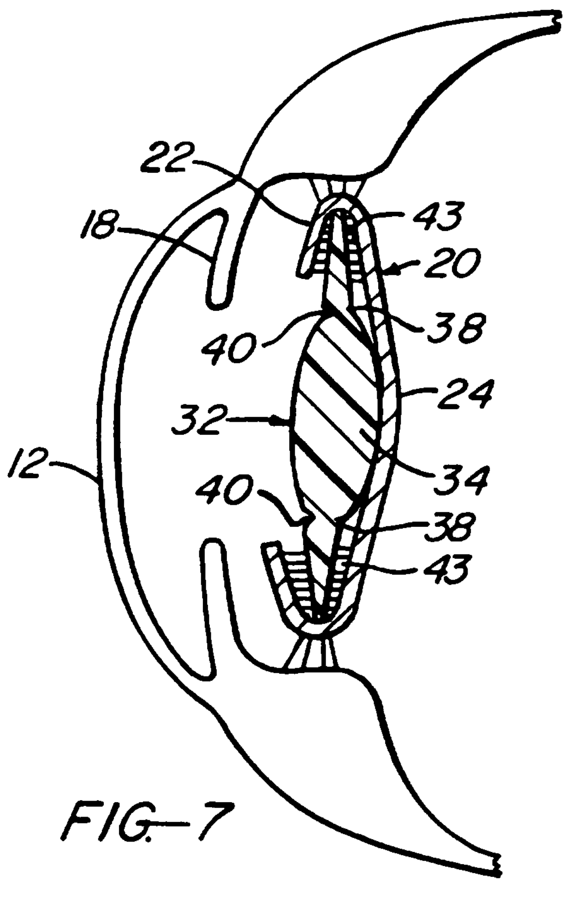

FIG.—7

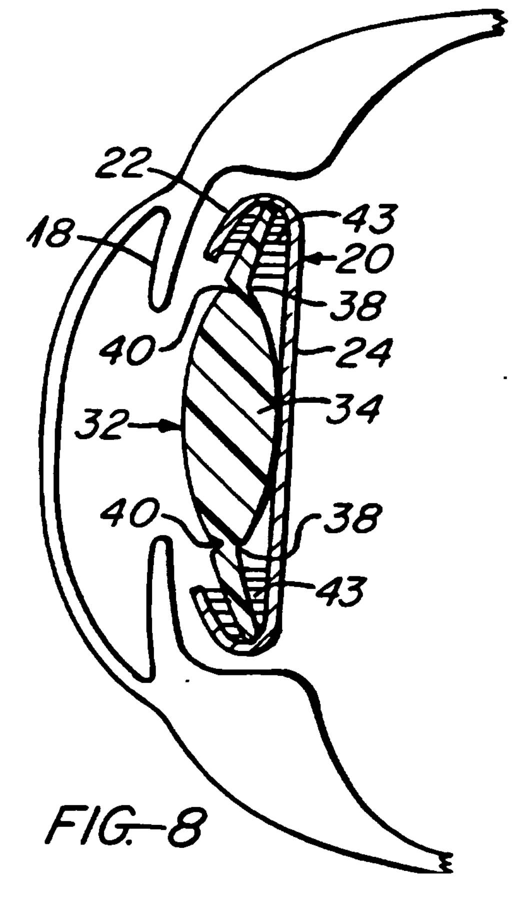

FIG.—8

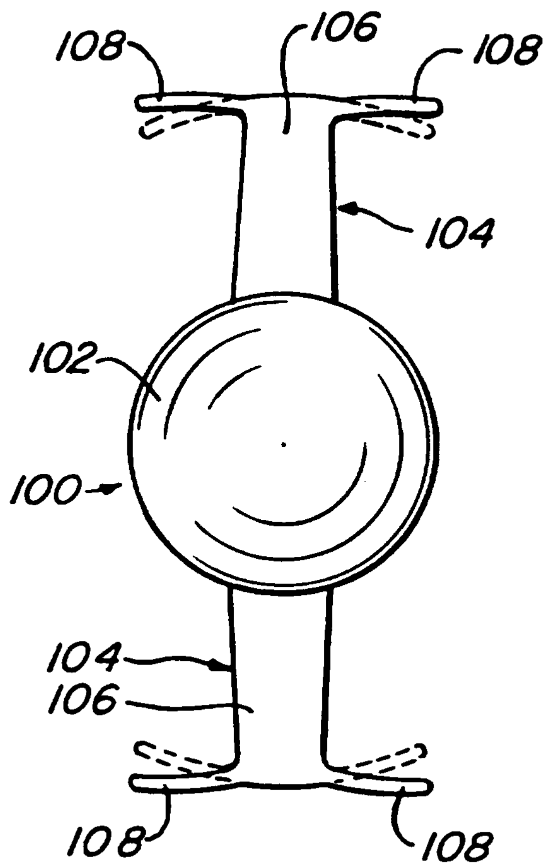

FIG.—9

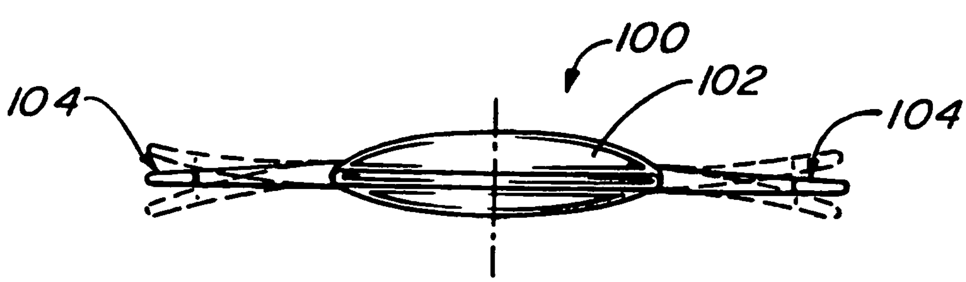

FIG.—10

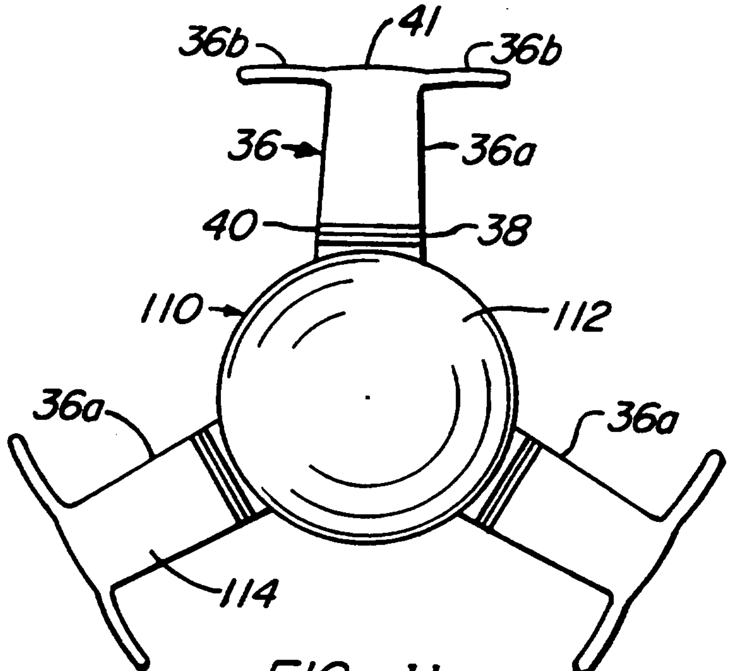

FIG.—11

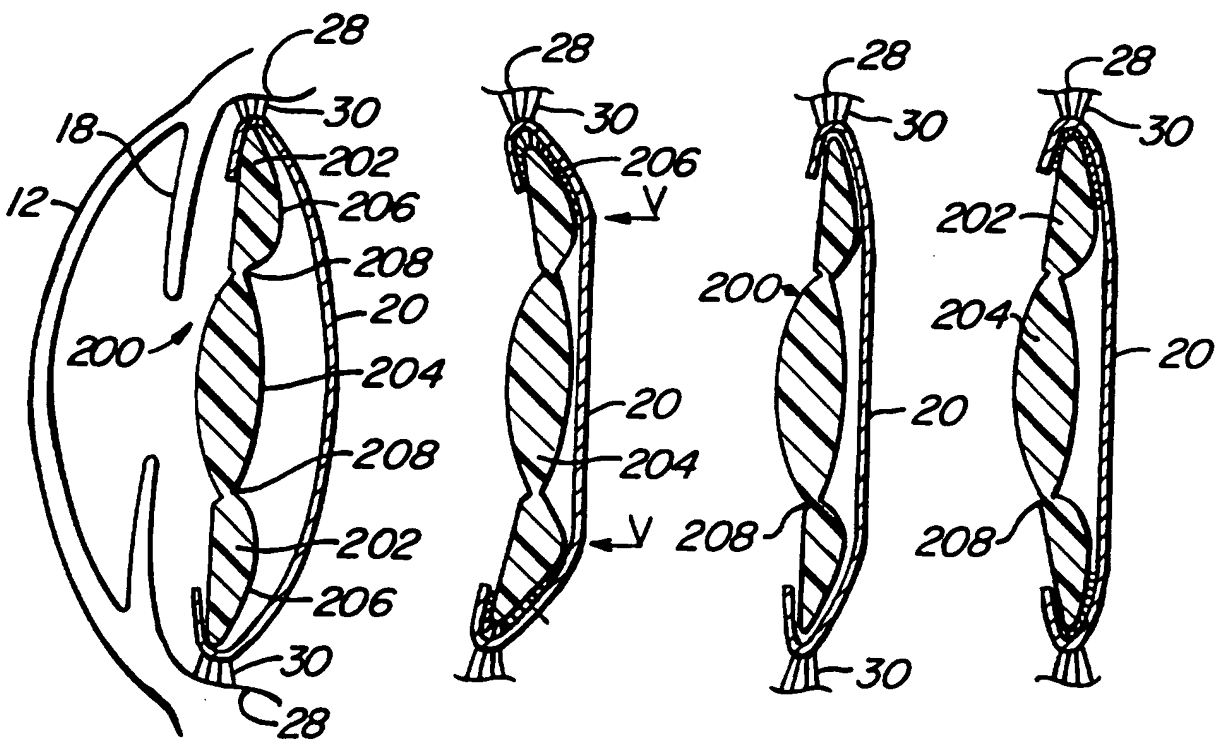

FIG.—12 FIG.—13 FIG.—14 FIG.—15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/01652

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A61F 2/16
US CL :623/6
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 623/6

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 4,254,510 (TENNANT) 10 March 1981, see entire document.	1-4, 7, 11-15, 18-19, 35-42 ---------------- 6. 16, 17, 43-46
X	US, A, 4,840,627 (BLUMENTHAL) 20 June 1989, see entire document.	37-42
Y	FR, A, 1,103,399 (MICROTTICA) 18 May 1955, see Figs. 3-5, and 9-14	6, 16, 17, 43-46

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

01 APRIL 1996

Date of mailing of the international search report

13 MAY 1996

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